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EPA INHALABLE PARTICULATE (IP) EMISSION FACTOR DEVELOPMENT PROGRAM

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ABSTRACT FOR ANNUAL MEETING PAPER NUMBER 83-21.1

EPA INHALABLE PARTICULATE (IP) EMISSION FACTOR DEVELOPMENT PROGRAM, D.L.Harmon, U. S. Environmental Protection Agency, Research Triangle Park, N.C. 27711.

At the request of EPA's Office of Air Quality Planning and Standards (OAQPS), the Office of Research and Development (ORD) is conducting a study characterizing inhalable particle (IP) emissions from various sources for the development of emission factors. Three contracts were awarded in September 1979 to conduct source characterizations for IP emissions from major sources. The testing phase for these contracts is near completion, and individual reports on the major sources (which will include the IP emission factors) are being prepared for publication. The IP emission factors will be based on existing particle size data and the IP source characterization tests. This paper gives an overview of the EPA program to develop IP emission factors. Examples of IP emission factors based on individual source tests are also presented.

Characterization Program

Early in 1978, EPA's Office of Air Quality Planning and Standards (OAQPS) requested the Office of Research and Development (ORD) to conduct a study characterizing inhalable particle (IP) emissions from various sources for development of emission factors. As a result of this request, a task force on IP emission characterization was formed to develop a program for determining emission factors based on cutoff size for IPs from both controlled and uncontrolled sources. This task force has been meeting about once per month since February 1979 to direct the work for development of IP emission factors. The committee has members from the following EPA organizations:

Office of Air Quality Planning and Standards (OAQPS),
Industrial Environmental Research Laboratory-Research Triangle Park (IERL-RTP),
Industrial Environmental Research Laboratory-Cincinnati (IERL-CIN),
Environmental Sciences Research Laboratory (ESRL), and
Division of Stationary Source Enforcement (DSSE).

An early task for the committee was to establish a list of priority sources to be tested for IP emissions. Since the range of sources emitting IP was large and the time and funds available were limited, it was necessary to make use of existing data to the maximum extent practicable and test sources which would provide the highest practical level of return. The priority sources identified early in the program are listed in Table I. Changes made in the priority list since it was developed have been to add iron foundries and industrial roads and to eliminate primary zinc smelters (8.c) and incineration (11). At the time original priority list was developed and funding levels were established, funds were included for lower priority sources to be added when identified; however, budget reductions, delays in testing, and increased testing costs have eliminated any testing beyond that now planned.

When the IP emission factor program was first begun the Agency was examining the effects of several particulate size fractions including IP matter (then defined as $\leq$ 15 µm aerodynamic equivalent diameter), fine particulate ($\leq$ 2.5 µm aerodynamic equivalent diameter), and fractions between these size cut points. The IP fraction is based on particulate matter which can deposit in the conducting airways and gas exchange areas of the human respiratory system while breathing through the mouth. A fine fraction $\leq$ 2.5 µm is based on chemical composition and the bimodal size distribution of airborne particles and the predominant penetration of particles $\leq$ 2.5 µm into the gas exchange region of the respiratory tract.[1]

A large data bank (> 300 test series) of particle size data on various industrial sources was in existence prior to initiation of the IP emission factor program. The most useful data was taken with impactors which have an upper stage cutoff of 10 µm or less. For these data to be used to develop IP emission factors it was necessary to extrapolate from existing data to 15 µm. An extrapolation procedure was developed, and data from the Fine Particle Emissions Information System (FPEIS)[2], a data bank developed for EPA containing much of the existing particle size data, have been extrapolated to 15 µm. These data are adequate to provide IP emission factors for some industrial sources without additional testing.

During the time the IP emission factor program was being developed, it became apparent that the measurements problem for obtaining IP source data was much more difficult than originally believed. It was determined that a sizeable effort would have to be devoted to this area before any field measurements were actually undertaken. To this end a meeting was sponsored by EPA's IERL-RTP and ESRL, bringing together many of the nation's measurement experts to develop a program to provide the necessary measurement and sampling techniques and expertise. These measurement experts decided that a two-stage cyclone set would be the best device to use for point source sampling. Such a system was developed for EPA by Southern Research Institute to provide 15 and 2.5 μm size cuts. Before fabrication of these cyclone sets was complete, however, questions began to arise as to selection of a 15 μm upper limit for IPs. In the spring of 1980 it was decided to review the IP cut point with the possibility of selecting a cut point less than 15 μm. If the cut point was changed to something other than 15 μm the cyclones could no longer be used. At this time, the approved point source sampling method became an impactor with a 15 μm cyclone precutter. Data is reported as a continuous plot of emission factor vs particle size from 15 μm down. When the IP cut point is finalized the appropriate emission factor can be read from the graph. An example curve is shown in Figure 1.

It is necessary to obtain IP emission data on industrial fugitive sources as well as point sources. Four test methods have been used for sampling IP fugitive emissions depending on the characteristics of the site to be sampled:

Quasi-Stack Sampling,
Roof Monitor Sampling,
Upwind/Downwind Sampling, and
Exposure Profiling.

Where cooling and dilution of ducted gas streams result in the formation of condensed particles, it is necessary to measure these condensibles as part of the IP emissions. One of the early tasks in the IP program was to develop a condensibles sampler. A prototype device was designed, fabricated, and field- and laboratory-tested by Southern Research Institute. It was intended that each contractor doing IP emission testing for EPA would fabricate one or more of the condensible samplers developed by Southern Research; however, by the time the sampler was developed it was not cost effective to fabricate separate samplers with the limited funds remaining for testing, so all condensible testing for the IP emission factor program is being done with the prototype unit.

In September 1979, as the result of a competitive procurement action, contracts were awarded to three IP characterization contractors (GCA Corporation, Midwest Research Institute, and Acurex Corporation) to conduct plant surveys and source assessments for IPs and to support OAQPS in the development and implementation of an IP standard. The scope of work for these contracts requires the contractor to conduct on-site plant inspections or surveys for the purpose of defining and evaluating the particulate pollution problems and for determining the fugitive emission sources. Following approval of a test plan developed by the contractor for the sites selected by EPA, the contractor is to conduct tests for ducted particulate matter, fugitive emissions, and condensible particulate matter.

When the IP characterization contracts were initiated, it was planned to use EPA personnel from IERL-RTP and IERL-CIN who were familiar with the industries to be tested to select the test sites. This did not work out in most cases because many of the EPA personnel did not have adequate time to devote to test site selection. It was necessary to direct the IP characterization contractors to develop priority lists for some industries and recommend specific sites for testing. Early in the program, it was decided to try to work cooperatively with industrial organizations to gain access to test sites. Most of the industrial organizations contacted were willing to cooperate on this project, but working out the agreements was time consuming.

It was originally planned that much of the testing would be done early in the contract period, but this was not possible. In addition to the delays in test site selection and gaining access to test sites, significant delays resulted from the need to develop IP sampling equipment including the condensibles sampler and size selective inlets and elutriators for use in the fugitive measurements program.

It would have been desirable to conduct tests on several different sites for each source type, but the number of sites tested was limited by the funds available. Where possible, tests for IP emissions were combined with other EPA field tests to stretch the limited funds. Also, existing data are being used where possible to supplement IP testing. Table II lists the IP tests which have been completed to date.

All testing planned for paved urban roads, unpaved roads, and industrial paved roads has been completed. Tests at seven different steel plants have been completed, and tests at one additional steel plant are planned. Processes tested in steel plants include the casthouse, sinter plant, coke quench tower, basic oxygen furnace, hot metal desulfurization, Q/BOP, paved and unpaved roads, and coal piles. Tests at one lime plant were completed. Lime processes tested were a kiln controlled by an ESP, a kiln controlled by a fabric filter, material transfer, and product loading fugitives. IP emissions from kilns on a dry process cement plant and a wet process cement plant have been completed.

Tests on three ferroalloy electric arc furnaces have been completed. The furnaces tested were producing silicon metal, ferromanganese, and ferrosilicon. Tests at an iron foundry were completed for pouring and cooling operations. Tests at a secondary lead smelter were completed. Secondary lead processes tested were blast furnace metal and slag tapping and charging, agglomeration flue, refining kettle, and pigging machine. Slag and matte tapping operations were tested at a primary copper smelter.

Emissions from a drum mix asphalt plant have been measured, and plans are to measure the condensible emissions from a batch mix asphalt plant. Tests were completed at two pulp and paper plants. Pulp and paper processes tested were direct and nondirect contact evaporator type recovery furnaces, a lime kiln, and a smelt dissolving tank.

Because a large body of existing data is available on combustion source emissions, the only testing planned is for condensibles. Condensibles tests have been completed on a coal-fired utility plant, an oil-fired utility plant, and an oil-fired industrial boiler.

The task force on IP emission characterization agreed that emission factors would be developed for 11 source categories. These source categories were selected to include all of the IP testing scheduled but the categories used reflect changes in priority since preparation of the original priority list shown in Table I. As the testing is completed for a given source category, one of the three IP characterization contractors will be given the task of preparing a report on that category. This contractor will combine test results from all contractors, extrapolate valid existing data, and develop source category IP emission factors. Particulate emission factors for total suspended particulates from uncontrolled sources are now compiled in AP-42[3] (Compilation of Air Pollutant Emission Factors). The source category reports will contain a section in AP-42 type format which can be used to update AP-42 with size specific emission factors for controlled and uncontrolled sources. The source category reports, which will contain summaries of the IP test results, will be published as EPA reports.

Source category reports are being prepared for the following 11 source categories:

1. Paved Roads
2. Industrial and Unpaved Roads
3. Iron and Steel
4. Ferroalloy
5. Cement and Lime
6. Primary and Secondary Nonferrous Metals
7. Iron Foundries
8. Asphaltic Concrete
9. Kraft Pulp Mills
10. Combustion
11. Metallurgical Coke Manufacturing

Preparation of all source category reports has started. Drafts of all of the source category reports should be completed and submitted for peer review by late spring of 1983. It is planned to complete the peer review process and submit all of the source category reports for publication by October 1, 1983.

Test Results

The IP source testing included both mass testing using an EPA Method 5 or Method 17 sampling train and fractional size testing using cascade impactors with a 15 μm precutter. The total emission factors are calculated by dividing the total mass as determined with the mass train by the average production rate for the process during the test period. The total emission factor is usually reported as kilograms of particulate matter per metric ton (kg/MT) of product or pounds of particulate matter per ton (lb/ton). The size specific emission factors were calculated lated by applying the fractional size distribution as determined with the cascade impactor train to the total emission factor developed from the mass train results.

Test results from some of the source tests are discussed and presented below. The emission factors reported are for the individual tests. The final emission factors included in the source category reports will be based on all

data available for each source and may be different from the emission factors reported here for individual tests. More details on these tests are reported in papers presented by the three IP characterization contractors at the Fourth Symposium on the Transfer and Utilization of Particulate Control Technology held in Houston, Texas, on October 11-14, 1982.[4,5,6]

Asphalt Plant

The test results from the drum-mix asphalt plant are shown in Table III.[4] This plant was nearly new at the time of testing and was in excellent mechanical condition. Sampling was conducted at the inlet and outlet of a baghouse collector. Even though the data were collected over a period of several weeks (due to unfavorable weather conditions),it is felt that the emission factors obtained are at least generally representative of most drum-mix asphalt plants.

Dry Process Cement Plant

The emission factors for the dry process cement plant are shown in Table IV.[4] The kiln was operating at approximately 35 tons per hour and was equipped with a baghouse. Material exiting the kiln passes through a three-stage suspension preheater system to remove the bulk of the larger material prior to entering the baghouse. The baghouse inlet was sampled between the preheater and the baghouse inlet. The outlet was sampled on the main exhaust stack.

Lime Plant

The results of testing of the lime plant are shown in Table V.[4] Two kilns were operating in this plant. One kiln of 400 tons per day capacity was equipped with three electrostatic precipitators (ESPs) arranged in parallel; the other of 300 tons per day capacity was equipped with one five-cell baghouse. Both controlled and uncontrolled emissions were measured for each kiln. The dust control system on the conveyor belt transfer points was also sampled.

Blast Furnace Casthouses

Two different types of blast furnace casting emission control systems were tested.[5] At Plant A the roof monitor opening of the conventional older casthouse was sealed and connected via a 10 ft diameter duct to a positive pressure baghouse. Plant B used a newer blast furnace casthouse runner evacuation system. Four casting runner systems are available, each controlled by close fitting hoods connected to a positive pressure baghouse.

The runner evacuation system emission factors are three times higher than the building evacuation system emission factors as shown in Table VI. The runner evacuation system test results also show a larger percentage of large particles. The proximity of the evacuating draft to the hot metal and slag runners is a logical reason for the higher emission factors.

Basic Oxygen Furnace

A basic oxygen furnace (BOF) was tested to quantify uncontrolled (baghouse inlet) and controlled (baghouse outlet) secondary fugitive emissions.[6] The test program included the hot metal charging and tapping portions of the BOF cycle. Emissions from the BOF steelmaking facilities are controlled by separate primary and secondary air pollution control systems. Emissions captured by the secondary control system include fugitive fumes generated when steel scrap and molten iron are added to the open mouth of the steelmaking vessel and when steel is tapped into a ladle. Fugitive emissions from the hot metal transfer station and skimming station (inside the BOF) are also captured by this system. The primary system captures furnace emissions during the oxygen refining cycle. Table VII gives results of testing the secondary system during hot metal charging and steel tapping cycles.

Ferroalloy Industry

Emissions from three open electric submerged arc furnaces producing ferroalloys were sampled.[5] The resulting size-specific emission factors are presented in Table VIII for each test series. Baghouse outlet tests were conducted at poor sampling locations. Positive pressure baghouses with roof monitor type outlets are used at most ferralloy facilities. These tests were all conducted in each of the individual baghouse compartments, about 6 ft above the top of the bags, at a single sample point. The flow was below detectable limits; therefore, isokinetic sampling was impossible. Since all three facilities were tested in the same manner, relative differences are notable; however, the overall accuracy is questionable. Baghouse inlet tests were all conducted isokinetically in horizontal circular ducts.

Summary

Source testing to measure IP emissions from high priority sources is near completion. Results of these tests are being combined with existing data to develop IP emission factors for 11 source categories. Reports which will include the IP emission factors are scheduled to be submitted for publication on all 11 source categories by October 1, 1983.

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TABLE I. IP EMISSION FACTOR PRIORITY SOURCES

1. Paved and Unpaved Roads
2. Iron and Steel Manufacturing
3. Secondary Lead Smelters
4. Portland Cement Manufacturing
5. Lime Manufacturing
6. Asphaltic Concrete Manufacturing
7. Ferroalloy Manufacturing
8. Primary Nonferrous Smelters
   a. Copper
   b. Lead
   c. Zinc
   d. Aluminum
9. Kraft Pulp Mills
10. Combustion (Coal/Oil)
    a. Utility
    b. Industrial
    c. Commercial/Residential
11. Incineration

TABLE II. COMPLETED IP EMISSION TESTS

Source Category	Sources Tested
Paved Roads	Urban Paved Roads
Industrial and Unpaved Roads	Industrial and Rural Roads
Iron and Steel	BOF Primary Hot Metal Charge Steel Tap Hot Metal Desulfurization Paved and Unpaved Roads Coal Storage Pile Casthouse Q/BOP Primary Sinter Plant Breaker/Hot Screens
Cement and Lime	Lime Plant Kiln-ESP Kiln-Fabric Filter Material Transfer Product Loading Cement Plant Kiln-Wet Process Kiln-Dry Process
Ferroalloy	Electric Submerged Arc Furnace Silicon Metal Ferromanganese Ferrosilicon
Iron Foundry	Pouring and Cooling
Primary and Secondary Nonferrous Metals	Secondary Lead-various ducted and fugitive sources Primary Copper-matte tap, slag tap, and idle ladle
Asphaltic Concrete	Drum Mix Plant
Kraft Pulp Mills	Recovery Furnace-nondirect contact evaporator Recovery Furnace-direct contact evaporator Lime Kiln Smelt Dissolving Tank
Combustion	Coal-Fired Utility Boiler-condensibles Oil-Fired Utility Boiler-condensibles Oil-Fired Industrial Boiler-condensibles
Metallurgical Coke Manufacturing	Quench Tower

TABLE III. EMISSION FACTORS FOR AN ASPHALT PLANT

Sample Location	Emission Factors (kg/MT)[a]			
	Total	< 2.5 μm[b]	< 10 μm[b]	< 15 μm[b]
Uncontrolled Side of Baghouse	15.5	0.85	3.6	4.1
Controlled Side of Baghouse	0.035	0.005	0.01	0.015

[a]Kilogram of particulate matter per metric ton of asphalt paving produced.
[b]Aerodynamic diameter.

TABLE IV. EMISSION FACTORS FOR A DRY PROCESS CEMENT PLANT

Sample Location	Emission Factors (kg/MT)[a]			
	Total	< 2.5 μm[b]	< 10 μm[b]	< 15 μm[b]
Uncontrolled Side of Baghouse	110	19	44	47
Controlled Side of Baghouse	0.38	0.13	0.30	0.30

[a]Kilogram of particulate matter per metric ton of product.
[b]Aerodynamic diameter.

TABLE V. EMISSION FACTORS FOR A LIME PLANT

Sample Location	Emission Factors (kg/MT)[a]			
	Total	<2.5 μm[b]	<10 μm[b]	<15 μm[b]
Kiln-Baghouse				
Uncontrolled Side	60	6.4	25	35
Controlled Side	0.055	0.015	0.030	0.040
Uncontrolled Side	186	1.7	29	80
Controlled Side	4.7	0.65	2.3	2.9
Conveyor Belt Dust Collector	1.1	0.04	0.10	0.11

[a]Kilograms of particulate matter per metric tons of product.
[b]Aerodynamic diameter.

TABLE VI. EMISSION FACTORS FOR BLAST FURNACE CASTING

Sample Location	Emission Factors (Kg/MT)[a]			
	Total	<2.5 μm[b]	<10 μm[b]	<15 μm[b]
Plant A	0.20	0.05	0.11	0.13
Plant B	0.65	0.10	0.16	0.17

[a]Kilograms of particulate matter per metric ton iron cast.
[b]Aerodynamic diameter.

TABLE VII. EMISSION FACTORS FOR A BOF

Sample Location	Emission Factors (kg/MT)[a]			
	Total	< 2.5 μm[b]	< 10 μm[b]	< 15 μm[b]
Hot Metal Charging				
Uncontrolled Side of Baghouse	0.063	0.015	---	0.038
Controlled Side of Baghouse	0.00024	0.00005	0.0001	0.00015
Tapping				
Uncontrolled Side of Baghouse	0. 073	0.033	---	0.036
Controlled Side of Baghouse	0.0013	0.0002	0.0004	0.0005

[a]Kilograms of particulate matter per metric ton of steel tapped.
[b]Aerodynamic diameter.

TABLE VIII. EMISSION FACTORS FOR FERROALLOY PLANTS

Sample Location	Product	Emission Factors (kg/MT)[a]			
		Total	< 2.5 μm[b]	< 10 μm[b]	< 15 μm[b]
Uncontrolled Side of Baghouse	Ferrosilicon	35	16	19	20
	Ferromanganese	14	8.7	11	13
	Silicon Metal	436	305	353	375
Controlled Side of Baghouse	Ferrosilicon	0.92	0.42	0.65	0.69
	Ferromanganese	0.24	0.11	0.19	0.21
	Silicon Metal	16.5	9.3	13.9	15.2

[a]Kilograms of particulate matter per metric ton of product.
[b]Aerodynamic diameter.

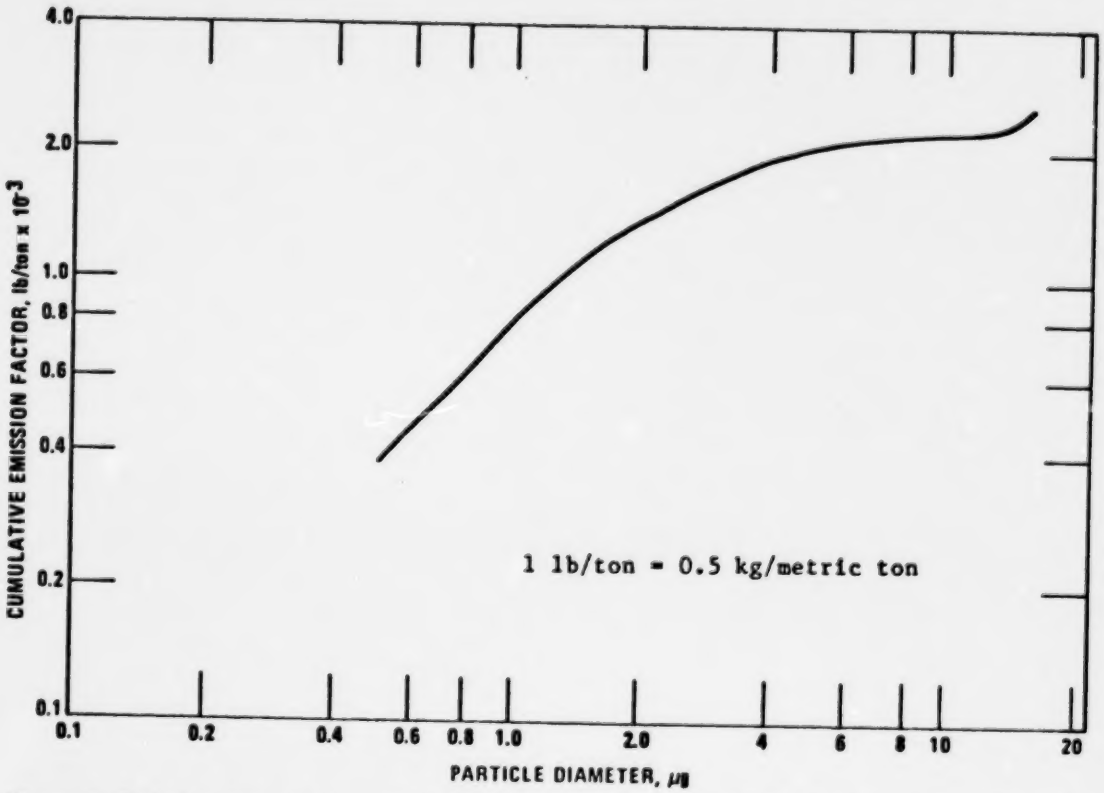

Figure 1. Emission factor for controlled emissions from hot metal desulfurization plant based on one test.